Agent - Based Traffic Simulation using Microscopic Modelling

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Certificate

This is to certify that the work in the project entitled *Agent-Based Traffic simulation using Microscopic modelling* by *Arijeet Mitra* is a record of an original work carried out by him under my supervision and guidance in partial fulfillment of the requirements for the award of the degree of *Bachelor of Technology* in *Computer Science and Engineering.*

To the best of my knowledge the matter embodied in the thesis has not been submitted to any other university/institute for the award oof any degree or diploma.

Prof. S.K. Jena

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Abstract

An agent is simply an object or class entity with its own attributes and methods. Agents simulate realistic behavior through efficient model abstraction while minimizing software complexity i.e. to synthesize life like systems to exhibit behavior of natural living systems . A microscopic model is able to simulate traffic in urban areas in real time for use in driving simulators. The vehicles considered in the simulation , namely user-driven vehicle at the center of the simulation model and other vehicles interact with its surroundings . Simulation is done in control zone and traffic light simulation is included only in this reduced control area. In order to understand vehicle dynamics , a wide range of microscopic models are used like car following model , lane changing model etc. which provides a realistic modeling of driver and vehicle behavior , and requires high computation resource. The primitive models developed here are the basic intersection model of traffic lights. The color changes indicating the permission for one lane to process the instruction one at a time whereas the other lane needs to wait. It is observed that for random traffic along the lanes the waiting time remains regular along both directions. Traffic light alternates between green and red phase. By varying the time of green and red phases, the number of vehicles is controlled and observation are carried out in 6 lanes. This greatly depends upon the traffic density or throughput of the vehicles. When traffic density of highway tends to exceed the critical density the ramp metering sets up limits the inflow of vehicles in order to avoid traffic congestion and breakdown. Traffic throughput is observed through the waiting time associated with each vehicle. Unlike highway environments , in urban nature consists of different other constraints governed by VANET routing protocols to carry and forward mechanism to deal with challenges. VANET enables the vehicles to communicate which are out of sight or even out of radio transmission. We analyze a unique feature of VANET protocol that vehicles of different types move like clusters due to influence of traffic lights. In this paper the concept of using heterogeneous infrastructures like cars, buses are used to improve network connectivity , and the transmission quality of each road segment along with vehicles are considered.Open street map is a valuable source for real world map data. However the data in the map is not completely ready for traffic simulation. For good simulation the map must be followed through several steps. The proposed randomized traffic light controller is capable of communicating with the neighbor junctions and manages phase sequences and phase length adaptively. A real case study of complex traffic junction is simulated having four intersections. Average flow density, average delay time , and link overflow of all four intersections are used as performance indices.

***Keywords*:** microscopic model, control zone, vehicle dynamics

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Chapter 1

Introduction

1.1 Agent Based Technology

An Agent is an class or a entity with its own behavior , that is with its own attributes and methods in a mathematical manner. To be more precise the agents as individual units communicate with each other to induce intelligence to the system. An agent behaves differently under different situations. One of the most promising feature of Agents is that they have the ability to adapt , that is make decision in a changing environment.

Agent- Based modelling (ABM) , is an approach to simulating the behavior of the complex system in which the agents interact with each other and with their environment using simple local rules of interaction . The Successes of this approach in predicting traffic flow in metropolitan areas, and the behavior of economic systems have generated further interest in this powerful technology.

In many cases, ABM is the most natural for describing and simulating a system composed of behavioral entities. For example, it is more natural to describe how vehicles move in a lane than to come up with the equations that govern the dynamics of the density of vehicles. Because the density equations result from the behavior of vehicles, the ABM approach will also enable the user to study aggregate properties.

The flexibility of ABM can be observed along multiple dimensions. For example, it is easy to add more agents to an agent-based model. ABM also provides a natural framework for tuning the complexity of the agents: behavior, degree of rationality, ability to learn and evolve, and rules of interactions[24].

The economic impact of traffic management grows each day. Well-designed and well-managed highway systems reduce the cost of transporting goods, cut energy consumption, and save countless person-hours of driving time. To reduce congestion, many countries have been investing heavily in building roads, as well as in improving their traffic control systems.On the other hand once the computer environment is established for social phenomena, the research cost will be much lower than the traditional research approaches. Also computers can implement complex simulation processes in several minutes at most.

The last major issue in ABM is a practical issue that must not be overlooked. By definition, ABM looks at a system not at the aggregate level but at the level of its constituent units. Although the aggregate level could perhaps be described with just a few equations of motion, the lower-level description involves describing the individual behavior of potentially many constituent units. Simulating the behavior of all of the units can be extremely computation intensive and therefore time consuming. Although computing power is still increasing at an impressive pace, the high computational requirements of ABM remain a problem when it comes to modeling large systems[24].

One must be careful, then, in how one uses ABM: for example, one must not make decisions on the basis of the quantitative outcome of a simulation that should be interpreted purely at the qualitative level. Because of the varying degree of accuracy and completeness in the input to the model (data, expertise, etc.), the nature of the output is similarly varied, ranging from purely qualitative insights all the way to quantitative results usable for decision-making and implementation[24].

1.2 Motivation

Traffic congestion is a major problem , and with increasing volume of traffic at steady rate it gets worse to control traffic by the conventional methods. In modern cities, traffic on major roads is abundant, and steps have to be taken to keep the traffic flowing at an acceptable speed. Over the years the traffic density of the roads will keep on increasing in spite of governments efforts towards the improvements in road infrastructure and promoting the public vehicle systems with high Occupancy Vehicles. This is because the number of vehicles on the road is increasing indefinitely. This makes it a most challenging problem for future. This is where technology needs to step in to. There are many schemes for reducing congestion; i.e. using High occupancy vehicles(HOV) , lane changing , controlling speed of vehicles , controlling the traffic light phases in case of urban traffic intersection. However when it comes to implementation these schemes remains at the back door. For countries like South Korean with advanced Road infrastructure and use of navigators in every vehicles have considerably reduced congestion . However it is unreliable for populated countries like India, China etc.. This is because of the High Latency, overload of Satellites , and the cost that comes with the implementation may induce more harm than good. There is a need for a agile and flexible technology which would allow the vehicles to take their own decisions instead of relying on some third party like satellites.

1.3 Problem Definition

The objective of this project is to show the traffic simulation is a worthy tool for traffic engineers for evaluating alternating schemes ; and then to study the effects of changes introduced through graphs. It aims at unique traffic simulation systems that can be used to study traffic theory and asses network infrastructure and control changes. This constitutes simulating different types of road networks . he other objectives include gaining an understanding of traffic theory, learning the major features and issues of traffic simulation and evaluating agent-based modeling as a means of simulating traffic. This is to show that the traffic simulation tool is a worthy tool for traffic engineers to reduce congestion in urban networks and simulation with the different models in concern. Agent communication includes enabling the communication between the car to car , car to infrastructure , and heterogeneous cars communication. The changes and the effects included in the traffic simulations of various road networks helps to save a lot of time and economy.

1.4 Structure of Thesis

The Thesis is structured as follows :

CHAPTER 2 is the Literary survey as Background. It focuses on describing the problems of Traffic Congestion and various works done in this area.
CHAPTER 3 is the Introduction to the Traffic Simulators of different types in different scenarios.
CHAPTER 4 tells us about the Proposed work and the models proposed from the basic preexisting models.
CHAPTER 5 shows the implementations in stages and details of results from testing on the problem.

Project conclusions and the future works in the area is presented in CHAPTER 6.

Chapter 2

Background

2.1 Traffic Congestion

Traffic congestion has been the most challenging problem on roads throughout the world for many years. The density of road traffic has increased rapidly in the recent years. Defacto In the UK, total road traffic has almost doubled since 1980 ,see Figure 2.1.The Department for Transport Forecasts show that the volume of road traffic will continue to rise at an alarming rate. These forecasts, as in the past have been the conservative estimates, suggests that traffic levels will increase approximately by 50 percent over the years 2000 and 2020 [4]. If this is the scenerio , then there is a need to understand the causes and effects of traffic congestion problem or it is could become a much worse problem in the near future.[25]

Traffic congestion is the major issue for many drivers; it generally results in journey delays as Latency, wasted time while waiting, increased pressure to reduce performance and can cause people loss of business especially in emergency situations. Also Congestion adversely affects the passengers, pedestrians, and mostly the users of buses and taxis, and causes more delay, stress and even more danger. The environment along with the local residents could be affected by large emissions or noise pollution associated to the vehicles. Congestion reduces the quality of life for many people and it deserves to be tackled in order to improve

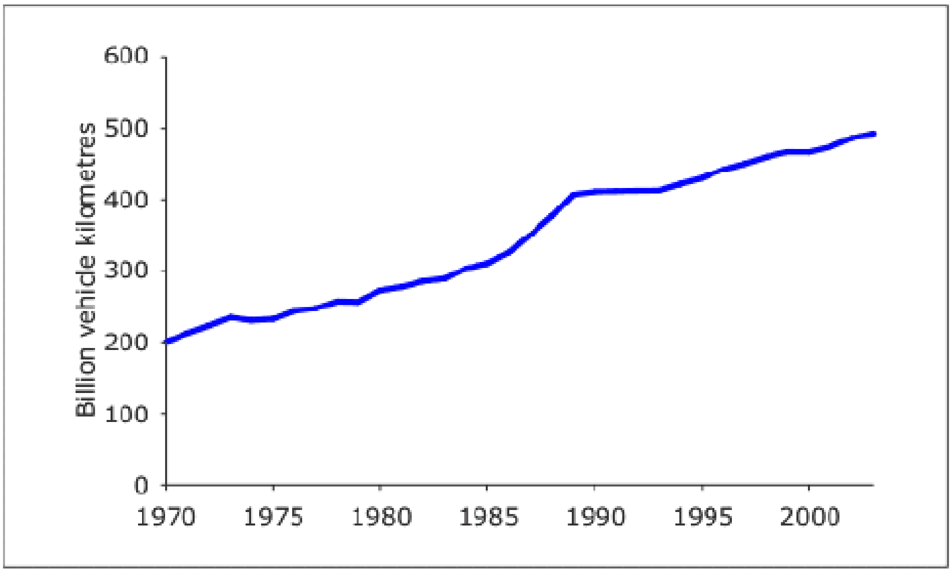

Figure 2.1: Level of Traffic Volume in UK[25]

transport for everyone.[25]

2.2 Tackling Traffic Congestion

Many schemes have been designed and implemented for relieving congestion as a primary objective.However, These schemes have a varying effectiveness, and also it is not always obvious that, it will work best in a given situation. The most common methods are considered in the section 2.2.1, with an indication of their efficiency . There is a new scheme which is receiving a good deal of attention at present, it is the introduction of high occupancy vehicle lanes; this is discussed in Section 2.2.2.

2.2.1 Existing Schemes

The immediately obvious strategy is to increase the road capacity by building new roads or by improving existing roads infrastructure, but this could rarely work to reduce long-term congestion as is evident over the years. Congestion is self-managing problem, because traffic is governed as what is regarded as a tolerable level of the congestion; as the road capacity increases, the demand (traffic) also increases to fill the new capacity. This concept is known as Braess Paradox or Pigou-Knight analysis, which suggests that the " increasing the network capacity can often be not only ineffective, but also counterproductive ". This is also known as one of the most expensive ways for tackling congestion [20][25].

However, Improving the public transport is an accepted way to improve the overall transport in busy- congested areas such as city centers and urban intersections. This covers the bus lanes, and improving the other modes of transport and by increasing the awareness of the benefits of walking and cycling to the common masses. It is one of the major aims of the Governments plan for transport, and it is thought that if people feel that there are real alternatives to driving, then travelling will be a easier method for everyone [19].

An attractive remedial measure for reducing congestion is the Intelligent Transport Systems (ITS). It is concerned with the application of the electronic information systems to control, manage and improve the transports. This includes the real-time route guidance systems(a.k.a navigators) , then variable speed limits controlled by the computer systems, also real-time transport information such as the congestion levels, the delay expected for public transport, the variable message signs, and dynamic signal- timings . ITS makes it possible for many new traffic management opportunities, which helps to reduce the congestion by making the best use of the existing transport network[25].

Congestion charging, is a form of road pricing implemented in London, is also a way of reducing demand (traffic) by forcing the drivers to pay a fee while driving through a congested area such as a city centre or town market place . This form of restraint is basically designed to encourage the drivers to use the other forms of transport when travelling in an extremely congested area, and it is very effective at reducing or eliminating the congestion as well as improving the air quality and the road safety, with more predictable travel, and possible profits. However, drivers often view it as an unfair money- making scheme, congestion could be increased around the edges of the charging zone as drivers would avoid it,this leads to more cost for travelling within the zone, and reduced profits for businesses just inside the zone[25].

2.2.2 High Occupancy Vehicle Lanes

One of the attempt to improve the efficiency of congested roads is to implement one or more high occupancy vehicle (HOV) lanes. These lanes are only used by a vehicles carrying more than a certain number of passengers. Similar to bus lanes, they could only be used by buses, taxis, and also by any other vehicle making efficient use of the road by carrying more passengers. The HOV lanes are intended to promote the use of public transport and car pooling (car sharing) facility ,in order to ease the congestion by reducing the number of cars on the road, and to improve efficiency by increasing the throughput of vehicles by carrying more people [7].

HOV lanes appear to be the state-of-the-art technique for tackling the traffic congestion in the United Kingdom. However, Only a few schemes have been implemented till date, and have been involved in dual carriageways . However, there are now new proposals in some place to convert one lane on a motorways into a HOV lane during the peak periods .There is a fair amount of controversies on the HOV lanes, as many drivers only perceive the larger amounts of congestion because of them, especially for a single occupant vehicles. The USA has been at the front for using HOV lanes, and have common standards are in the place for their planning and design. The majority of the schemes involve restricting the use of HOV lane to vehicles with two or more occupants [7].

The measures used to evaluate the performance of HOV lanes is the average vehicle occupancy (AVO) of a road. In the USA, the primary objective were to increase the AVO, regardless of the resulting traffic flows. It is generally accepted that the introduction of a HOV lane will increase the AVO by 10-15 percent, however the resulting volume of vehicles are not so readily available. Depending on local conditions, the introduction of a HOV lane is expected to reduce the number of vehicles by approximately 10 percent through increased occupancy and some vehicles taking different routes [7][25].

2.2.3 Local Traffic Study

In South Gloucestershire , traffic congestion have significantly increased for more than the national or county average, especially in the northern fringe of the Bristol area, due to the location of the area along the M4/M5/M32 corridors [4]. The University of the West of England is located along this north fringe, supporting over 2,000 staff and 16,000 students. The following map shows the location of the UWE campus in relation to the motorways and the Avon Ring Road/Cold harbor Lane HOV lanes (shown in green) [4].

In 1998, HOV lanes were introduced on the Avon Ring Road for use by cars and vans with two people or more, buses, coaches, motorcycles and emergency vehicles. South Gloucestershire Council considered the options, and found that HOV lanes were the best value for money improvement available to decrease congestion. The aim of the project is to give an advantage to car sharers and bus users, i.e. decreased journey times. An online car-sharing database was also setup to allow drivers to find a car-sharing partner [4].

2.3 Traffic Theory

2.3.1 Measuring Traffic Flow

This involves the study of the traffic flows as an essential for the design of better road networks. If traffic flow could be completely understood, then the traffic levels could be predicted and congestions would be forecasted and hence avoided. In order to understand this phenomenon,there is a need to start by looking at the roads history behavior . Traffic surveys are often used to provide means for measuring the current situation, and involves counting the number of vehicles going past a point in a certain amount of time. The standard flow or capacity of the average road at an optimal condition is generally accepted to be around 2,000 vehicles per hour, per lane [6].

However, simply by knowing the flow rate is not useful enough , for example, say 5 vehicles can pass a counter in one minute with spaced-out at a 60mph or from nose-to-tail in a jam. Then the traffic density will describe the number of vehicles in a certain amount of road, and it requires the vehicles speed in addition to the flow rate for calculations . Density is basically measured as vehicles per km per lane. The optimal density on a standard road would be around 40 vehicles per km per lane. At this level of density, the flow rate would be at the maximum, i.e. 2,000 vehicles per hour, per lane [5].

This method allows one to learn about the traffic flow through a junction or small number of roads, but to gain an overall picture of traffic is required.For this purpose say , Individual trips may be represented as an origin-destination (O-D) matrix, which allows one to represent the number of trips to and from any two destinations. The O-D matrix is an n * n array, where n is the number of origins or destinations considered [6].

2.3.2 Modelling Traffic Flow

The approach was to treat vehicles as individual units instead of a continuous flow, and see what behaviour emerges when the vehicles are given simple rules to follow. Each vehicle would move according to the vehicle ahead, speeding up or slowing down to match its speed while maintaining a safe distance between cars[25].

The results from these models and from traffic studies show that flow rate and traffic density are linked in an interesting way. Normally, flow rate increases as density increases, that is, more vehicles are on the road without any having to slow down. However, when the density reaches a so-called critical density, the flow rate begins to decrease and the traffic becomes congested. An interesting observation is that of a hysteresis effect that with density increase above the critical density , it is possible for the traffic flow to continue to increase in a meta stable or bi-stable state. In this state, any change in the traffic flow can cause the traffic to become congested.[2]

An effect of all this modelling is for the better understanding of why traffic jams tend to appear with no apparent cause. When the traffic density exceeds the critical density,then at any point a fluctuation can cause start-stop in traffic. Traffic jams of this form (with no bottleneck cause) moves upstream through the traffic, which is easily observed through a graph of space-time showing the position of each vehicle in time, see Figure 2.4. Until the density decreases, the traffic jam will live on, often get worse and sometimes split into multiple regions of stop-start traffic [5].

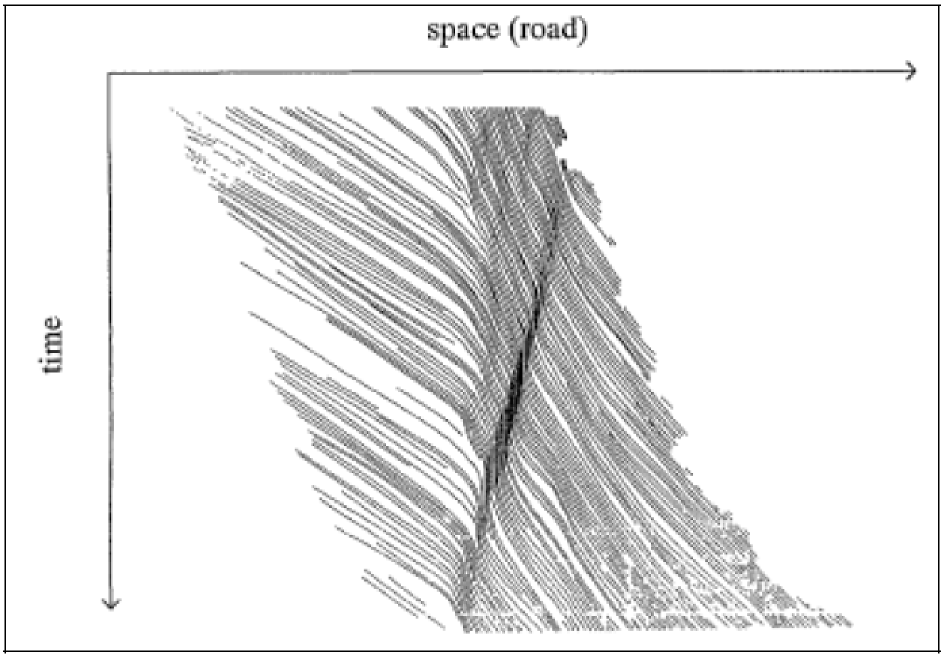

Figure 2.2: Space-time graph where the lines represents the Vehicles[25]

Hysteresis is a property of a systems that exhibit a delayed response to the state changes, and seen as a lag between the states. A States moved to the unstable state, then it cannot return to the bi-stable or the free-flow state until the density comes lower than the critical density (A). That is , the hysterical effect happens in only one direction, with density increase. These conditions are also observed during phase transitions in solids, liquids and gases. This effect could be achieved in cellular models by implementing the slow-to-start rule. This is done by making the traffic accelerate slower out of the stopped traffic, than at any other time [2].

Therefore, to model a traffic jam on the motorway with the free flow, metastable and congested state transition, however real traffic exhibits more behaviours

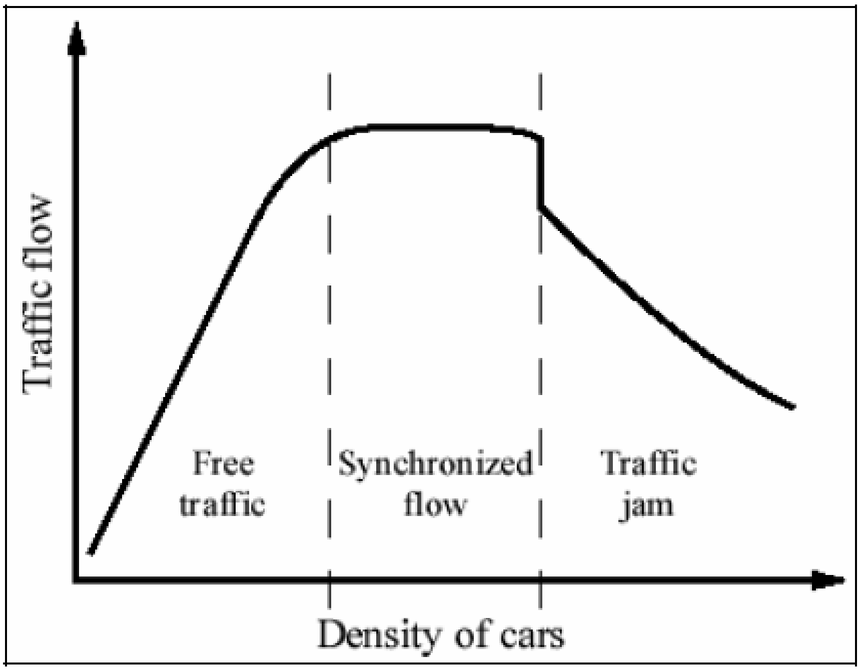

Figure 2.3: Traffic Flow density incorporating synchronized flow[25]

than these states provide. Kerner and Rehborn proposed that there are two different states of congested traffic: one is the traffic jam where no one moves (point D on Figure 2.3) and the other being a synchronised state. This state is possible if the speed of all the traffic is more or less the same, and no vehicles stop completely. In this state, high-density traffic can maintain a reasonably high flow rate without breaking down into stop-start traffic ,see Figure 2.5 [23]. This state can be reached from either the free-flow or metastable states discussed above. Synchronised traffic can be modelled by incorporating a comfort factor where drivers aim to drive smoothly with less hard acceleration or deceleration. Researchers still debate the conditions that lead to synchronised traffic; it often occurs at road features such as entry and exit ramps, but sometimes occurs out of nowhere in normal conditions [23][25].

2.3.3 Understanding Drivers

The Drivers are difficult to analyse because being human their behavior is unpredictable and individualistic . In general, drivers are not at all aware of the global state of the traffic system, and they can only perceive with the local conditions. The Drivers are also emotionally complex, and change their behaviour , for no apparent reason. One problem with these many schemes is that they only rely on drivers heeding for the advice given to them. For example, on the M25 motorway, variable message signs are often used to alter the speed limits of the carriageways to optimise traffic flow. However , without penalties such as for speed cameras . many drivers would simply ignore . these limits and decide that they know better. Drivers are not always be expected to do what seems to be rational, but for the purposes of this project, it will be assumed that they regard their safety with the utmost importance, and otherwise they try to maximise their utility of the situation through their driving decisions[25].

Chapter 3

Traffic Simulators

3.1 Simulation Classifications

Ferber [18] describes simulation as a very active branch of computer science, which consists of analysing the properties of theoretical models of the surrounding world. There are many types of computer simulation; the relevant classifications are summarised below :

Stochastic simulations use random number generators to model chance and randomness. It is unlikely that two runs of a stochastic simulation would be the same, but most generators use seeds that can be set to produce the same set of numbers each time, making reproducible results possible. Deterministic simulations are those that are inherently predictable, always producing the same output for a given input. Deterministic models are useful for experiments where the results need to be reproducible, however most real-world phenomena such as traffic have some degree of chance and therefore require stochastic simulation[25][10].

Simulations can be classed as continuous or discrete. Continuous models take the form of equations using variables that correspond to real values. By solving the equations, the state of the model at any given point in the simulation can be calculated. Discrete simulations represent reality by modelling the state of the system and its state changes after time or events have passed. There are two types of discrete simulation: discrete time models and discrete event models. Discrete time models (time-sliced) are those that split the simulation into fixed time intervals. At each interval, the state of the model is updated using functions that describe the interactions. Discrete event models (event-oriented) are those which maintain a queue of events scheduled to happen in order of time, each event representing the change of state of an element in the model. The simulator processes the events in order, and each one can alter the event queue. Section 3.6.4 looks at the implementation issues presented by discrete time and discrete event simulation[1][10].

3.2 Macroscopic vs. Microscopic

Traffic simulators can be microscopic or macroscopic depending on the level of detail required. Macroscopic simulators model the flow of traffic using high-level mathematical models often derived from fluid dynamics, thus they are continuous simulations. They treat every vehicle the same, and use input and output variables such as speed, flow and density. These simulators cannot differentiate between individual vehicles, and usually do not cater for different vehicle types. They lack the ability to model complex roadways, detailed traffic control features or different driver behaviours[16][8][17]. Macroscopic simulators are most useful for the simulation of wide-area traffic systems, which do not require detailed modelling, such as motorway networks and interregional road networks . This approach is not very realistic because in real life there are many different types of vehicle driven by different individuals who have their own styles and behaviours. However, it is fast and can be useful and accurate, but is not suited to urban models [16].

Microscopic simulators model individual entities separately at a high level of detail, and are classed as discrete simulations. Each vehicle is tracked as it interacts with other vehicles and the environment. Interactions are usually governed by car-following and lane-changing logic. Rules and regulations are defined to control what can and cannot be done in the simulation, for example speed limits, rights of way, vehicle speed and acceleration[40][31]. Traffic flow details usually associated with macroscopic simulation are the emergent properties of the microscopic simulation.

Microscopic simulators can model traffic flow more realistically than macroscopic simulators, due to the extra detail added in modelling vehicles individually [16]. Microscopic simulators are widely used to evaluate new traffic control and management technologies as well as performing analysis of existing traffic operations [17][25].

3.3 Simulation Scenarios

Traffic simulations can be broadly classified by the type of road network and features they can simulate. The two main classes for simulators are those designed for motorway and urban environments. Simulators supporting a motorway environment focus on multiple-lane high-speed motorways. Much of the complexity required for a city environment does not need to be modelled, and the simulation can focus on vehicle behaviour and interaction. Motorway environments can be simulated accurately by both macroscopic and microscopic simulators [12]. The main features of a microscopic motorway simulator are car-following and lane-changing behaviours. Junctions are sometimes modelled, allowing entry/exit rate to be varied to test the efficiency of the motorway under varying traffic load. Practical uses include studying the effect of motorway accidents, stop-start congestion, speed limits, ramp metering and lane closures on traffic flow [9][12].

An urban environment is one of the most difficult and complex traffic scenarios [16]. In contrast to motorway environments, urban environments have a traffic flow that is interrupted by intersections, traffic lights, roundabouts and other features. In addition to the extra road features, realistic urban simulators should model not only different classes of vehicle, but also pedestrians, cyclists and public transport systems [14]. Urban traffic networks are usually very complex with many road sections and intersection points, often with conflicting traffic flows [15]. They usually have to manage a large number of vehicles on small road sections, which can result in a large amount of congestion [13]. Microscopic simulators are well suited to urban environments as vehicles can respond individually to the road features. Macroscopic simulators are not able to model the complexity of urban environments; they are only used to provide abstract flow details [25].

3.4 Simulators and Tools

3.4.1 NetLogo

NetLogo is a programmable modeling environment for simulating natural and social phenomena. NetLogo is particularly well suited for modeling complex systems developing over time. Modelers can give instructions to hundreds or thousands of "agents" all operating independently. This makes it possible to explore the connection between the micro-level behavior of individuals and the macro-level patterns that emerge from their interaction [22].

NetLogo lets students open simulations and "play" with them, exploring their behavior under various conditions. It is also an authoring environment which enables students, teachers and curriculum developers to create their own models. NetLogo is simple enough for students and teachers, yet advanced enough to serve as a powerful tool for researchers in many fields.

NetLogo has extensive documentation and tutorials. It also comes with the Models Library, a large collection of pre-written simulations that can be used and modified. These simulations address content areas in the natural and social sciences including biology and medicine, physics and chemistry, mathematics and computer science, and economics and social psychology. Several model-based inquiry curricula using NetLogo are available and more are under development.

NetLogo runs on the Java virtual machine, so it works on all major platforms (Mac, Windows, Linux, et al). It is run as a standalone application. Models and HubNet activities can be run as Java applets in a web browser.

System Requirements - NetLogo runs on almost any current computer.
Application Requirements
Windows NetLogo runs on Windows 7, Vista, 2000, and XP. The NetLogo installer for Windows installs Java 6 for NetLogo's private use only. Other programs on your computer are not affected.

Mac OS X
Mac OS X 10.4 or newer is required. (NetLogo 4.0 was the last version to support 10.3 and 10.2.) We recommend you use Software Update to ensure that you have the latest Java.

Other platforms
NetLogo should work on any platform on which Java 5 or later is installed. Java 6 or later is strongly recommended. (If you have any trouble, try using the official Java from Oracle, not some alternate. GNU libgcj does not work. Very recent versions of OpenJDK, 1.6.0.0-22.b22 or newer, may work; older ones don't.)

Why use NetLogo ?
NetLogo has a well-designed graphical interface and interface builder in one that allows the novice and expert alike to run, alter and develop models with ease. It provides many built-in widgets to alter simulation parameters at runtime, including sliders, buttons, and drop-down menus, and allows output in the form of graphs and variable monitors. Simulation time is measured in discrete ticks, and simulation speed can be adjusted by a slider above the display. It can provide deterministic simulation if the random seed is set before the simulation is run. It provides simulation of continuous time and space, a physics engine, collision detection, and allows realistic 3D physical simulations to be easily defined by the behaviour of agents. Simulations are programmed in an interpreted object-oriented language [22].

A number of urban traffic simulations have been developed using agent-based modelling, most utilising toolkits/libraries. Many have been developed by researchers and students, as commercial traffic simulators do not yet use the agent approach[22].

3.4.2 Visual Simulator (VISSIM)

This program analyzes the private and the public transport operations and under the constraints that such as lane configuration, and vehicle composition, and traffic signals etc... Hence , making it such a useful tool for these evaluation of the various alternatives based on the transportation and engineering and planning measures of the effectiveness. Accordingly, it also models the pedestrian flows , either exclusively or by combined with the private traffic or public transport [21]. VISSIM can be also applied as a useful tool in variety of the transportation problem settings. The following list provides a very selective overview of the previous applications of VISSIM simulator [21]:

1. The Development, evaluation and the fine-tuning of the signal priority logic: VISSIM can use the various types of a signal control logic. In addition to a built-in and fixed-time functionality , there are also several vehicle-actuated signal controls that are identical to the signal control software packages installed in this field. In case of VISSIM some of them are already built-in, and some can be docked by using add-ons and others can be then simulated through some external signal state generator (VAP) , which allows the design of the user-defined signal and control logic. Thus it virtually every signal control (incl. SCATS, SCOOT) that can be modeled and then simulated within the VISSIM , if either the controller details are then available or there is direct VISSIM interface available (e.g. VS-PLUS).

2. Evaluation and the optimization of the traffic operations in combined network of a coordinated and a actuated traffic signals.

3. Feasibility and the traffic impact study of integrating the light rail into the urban street networks.

4. Analysis of the slow speed weaving and the merging areas.

5. Easy comparison of various design alternatives including the signalized and the stop-sign controlled at intersections, roundabouts and at grade separated inter-changes.

6. Capacity and operations for analyses of the complex station layouts for the light rail and also bus systems have been analyzed with the VISSIM.

7. Preferential treatment solutions for the buses (e.g. queue jumps, bus-only lanes , curb extensions) also have been evaluated with the VISSIM.

8. With its own built-in Dynamic Assignment model, the VISSIM can also answer the route choice that are dependent questions such as impacts of the variable message signs and the potential for the traffic diversion into a neighborhoods of networks up to the size of a medium sized cities.

9. Modeling and then simulating the flows of pedestrians - in the streets and buildings that allow for a wide range of new applications.The VISSIM can simulate and visualize interactions between the road traffic and the pedestrians.

This simulation package of VISSIM , consists internally of two distinct parts, namely the exchanging detector calls and the signal status through an interface. The simulation generates the online visualization of the traffic operations and off .line the generation of the output files and gathering statistical data such as the travel times and the queue lengths.

The traffic simulator is an microscopic traffic flow simulation model that includes , the car following and the lane change logic. The signal state generator is the signal control software polling detector for information from the traffic simulator on discrete time step basis (say down to 1/10 of a second). It determines the signal status for the time step and then returns this information to traffic simulator.

The accuracy of the traffic simulation model is basically dependent on the quality of the vehicle modeling,that is the methodology of moving the vehicles through the network. In contrast , to a less complex models using a constant speeds and a deterministic car following logic, the VISSIM can also use the psycho-physical of the driver behavior model developed by WIEDEMANN (1974). The basic concept of the model developed using VISSIM is that , the driver of an faster moving vehicle first starts to decelerate when he reaches his individual perception of threshold to an slower moving vehicle. Since he exactly cannot determine the speed of those vehicle, his speed will also fall below that vehicles speed until he starts to slowly accelerate again and then after reaching another perception threshold. This results in an iterative process of the acceleration and deceleration[21].

Stochastic distributions of the speed and then spacing of thresholds also replicate the individual driver behavior characteristics. Its models have been calibrated through a multiple field measurements at the Technical University of Karlsruhe (since 2009 KIT Karlsruher Institut fr Technologie), Germany. A Periodical field measurements and their results updates of the model parameters ensure that any changes in driver behavior and the vehicle improvements are accounted for. VISSIMs traffic simulator do not only allows drivers on multiple lane roadways to react to their preceding vehicles , but it also allows the neighboring vehicles on adjacent travel lanes that are taken into account. Furthermore, while approaching a traffic signal , results in a higher level of alertness for the drivers at a distance of about 100 meters in front of the stop line.[21]. VISSIM can also simulate the traffic flow by moving the driver-vehicle-units through out the network. Every driver with his/her specific behavior characteristics are assigned to a specific vehicle. As the consequence, the driving behavior corresponds to the technical capabilities of the vehicle[21].

Attributes characterizing for each driver-vehicle unit can also be discriminated into three categories[21]:

1. The Technical specification of vehicle, such as :

   Length

   Maximum speed

   Potential acceleration

   Actual position in the network

   Actual speed and acceleration

2. The Behavior of the driver-vehicle units, such as :

   The Psycho-physical sensitivity thresholds of the driver , that is ability to estimate, aggressiveness etc...

   The Memory of driver

Acceleration based on the current speed and the drivers desired speed

3. Interdependence of driver-vehicle units includes :

   Reference to the leading and the following vehicles on its own and on the adjacent travel lanes

   Reference to the current link and to its next intersection

   Reference to the next traffic signal

Chapter 4

Traffic Models

This project focuses on developing intelligent vehicles. Introducing intelligence in everything around us is the most desirable means of human technology. A system is divided into components called agents where the agents communicate with each other to share their state information and makes decision. Similarly in Traffic control System consists of agents such as vehicles , roads, signals etc

In this project several traffic models will be build from simple to complex. Each model will model a particular phase of traffic scenario such as car following, lane changing, variable speeds, speed- limit, vehicle composition, signal phase control, traffic light controls etc

Their corresponding graphs of waiting time , speed tells us the ADT(Average Delay Time) for a road network. This information obtained could be very well communicated from vehicle to vehicle. However this may work for simpler models , for more complex models with very high traffic density the vehicles will be overloaded with the information to make a decision. In such cases other agents that is roads or Traffic signals can help the vehicles to make the decision. For example, Consider a road connected with a source at one end and connector at other end with a traffic light. The road could be mapped to other roads depending upon the traffic density of each roads. The road agents share this information which helps the vehicle to make decisions. Similarly the same information when shared with traffic light, could change the phase interval of red and green light to control traffic densities for each road segments.

Hence the information computed from each model is very helpful to avoid road congestions. The effects priors and later to introducing changes during experimentation could be observed through the graphs. These logics will then be aggregated into complex models such as Open Street Map Models imported from Google-Maps.

4.1 Vehicle Following Model

Car-to-Car(C2C) , Car-to-X(C2X) , and Car-to-Infrastructure(C2I) communication aims to improve the road safety and traffic efficiency by exchanging foresight information. Car Following Model exploits this property of Vehicles in real world environment. Several advantages of this can be categorised as follows :

1. Cooperative forward collision warning, namely, to avoid rear-end collisions
2. Traffic light optimal speed advisory, namely, to assist the driver to arrive during a green phase
3. Remote wireless diagnosis, namely, to make the state of the vehicle accessible for remote diagnosis

In a typical Car-Following Model Figure 4.1, each car maintains a constant distant with its preceding car and the successive car along the lane. hence though every car along a specific lane has its own speed with in the limits of the lane criterion , they induce a intelligence by controlling the speed to maintain distance between the cars to avoid collision and congestion.Say, When a selected cars approach closer to the the successive car with their inter distance less than the critical distance then the selected car decelerates and when the selected car comes closer to the previous car less than critical distance then the car accelerates.The control logic can be represented as [25]:

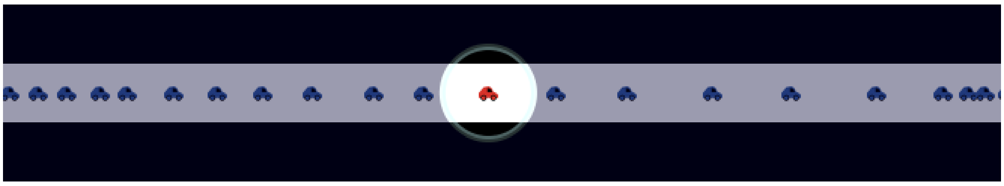

Figure 4.1: A Single lane model incorporating the vehicle following

IF (any vehicles in front within current stopping distance)
Slow down (using max deceleration)
ELSE
Speed up (using max acceleration, restricted by maximum speed)

This control logic sets the conditions to model the vehicle following model with anti-collision criterion.It model the core features of the vehicle interaction such that , the driver always stop if the vehicle in front of it stops. This effect is streamlined to all the other vehicles along the lane. Hence this model basically focuses on Collision Avoidance. However the ADT of the cars along the lane suffers.

4.2 Lane Changing Model

The lane changing behaviour implemented is based on the idea , that is the behavior of the vehicle depends upon the vehicles around it. The control logic in

Figure 5.2 is expressed below[25].

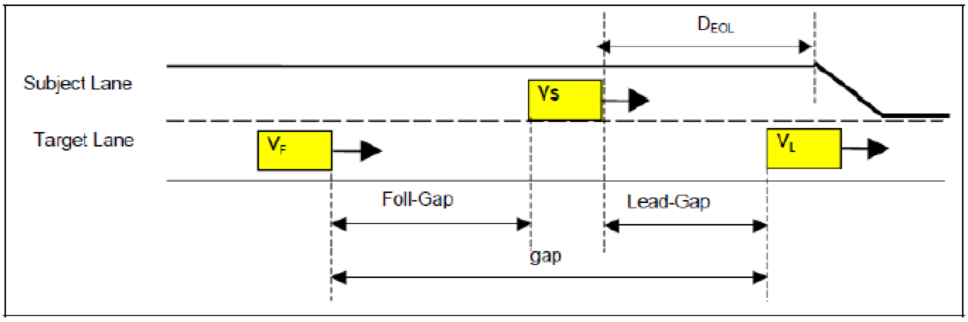

Figure 4.2: Algorithm for incorporating the lane changing

IF (current leader is slowing you down)

IF (safe distance ahead and behind on right lane)

MOVE RIGHT

ELSE

IF (safe distance ahead and behind on left lane)

MOVE LEFT

The lane changing model in Figure 5.3 is based upon two basic rules of incentive and safety. Incentive rule will be true if the gap if front of the vehicle in the other lane is greater than the current gap in the current lane, then it will be possible to change the lane. Safety rule determines if the gap with respect to the vehicle behind in the target lane is large enough so that the vehicle behind does not have to break its course at the instant it changes its lane.

The safety critical distance depends on the direction of moving when car is moving left , then it is possible that the car is travelling faster than the behind car . so a short distance will be safe.Whereas, while moving right , then the car checks the actual speed of the vehicle behind it and calculates , whether it is safe. To minimise the unnecessary lane changes, the vehicles will evaluate the situation in every one second, and it changes at most in every 5 seconds.

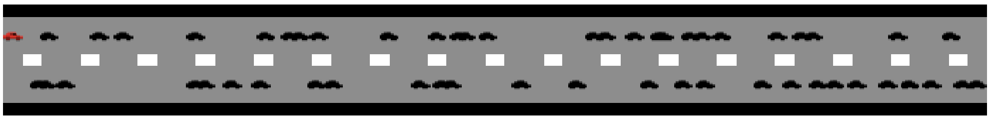

Figure 4.3: A model incorporating the lane changing

4.3 Traffic Light Control Model

4.3.1 Intersection Model

This model incorporates the Traffic light control using the signal as the agent . The only rule followed are governed by the red and green phases of the signals Figure 5.4.

The vehicles at the intersection moves either north - south or East- West . the vehicles at each direction gets its own ADT at regular peaks. each vehicle as an agent follows the collision avoidance mechanism . Each signal as agent communicates with each other , thereby alternating at regular intervals . An intelligent and novel traffic light control system based on WSN is presented[24]. where each WSN, consists of a group of traffic sensor nodes (TSNs), and it is designed to provide the infrastructure for traffic communication and to especially facilitate easy and large deployment of traffic systems.

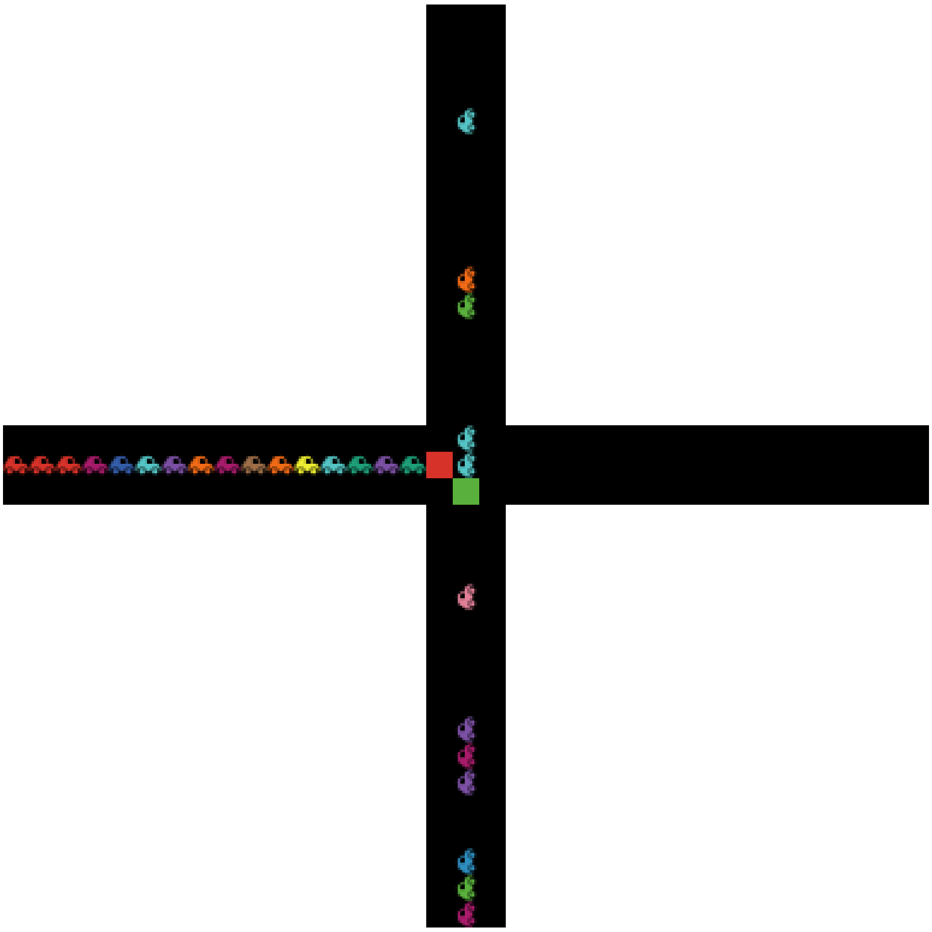

Figure 4.4: A Single lane Traffic Intersection model

4.3.2 Grid Model

This model is an array of a basic traffic intersection model at a wider scope .

Each vehicle as agent incorporates the vehicle following mechanism in the single lane . Each traffic light as agent communicates with each other to synchronize the traffic densities at the respective lanes. The re and green phase alternates at regular intervals . However there is streamlined effect of vehicles waiting for a "go" pass at all the junction points .

The traffic plan [24] should comprise of :

1. Traffic Phase as the group of directions that allow waiting vehicles to pass

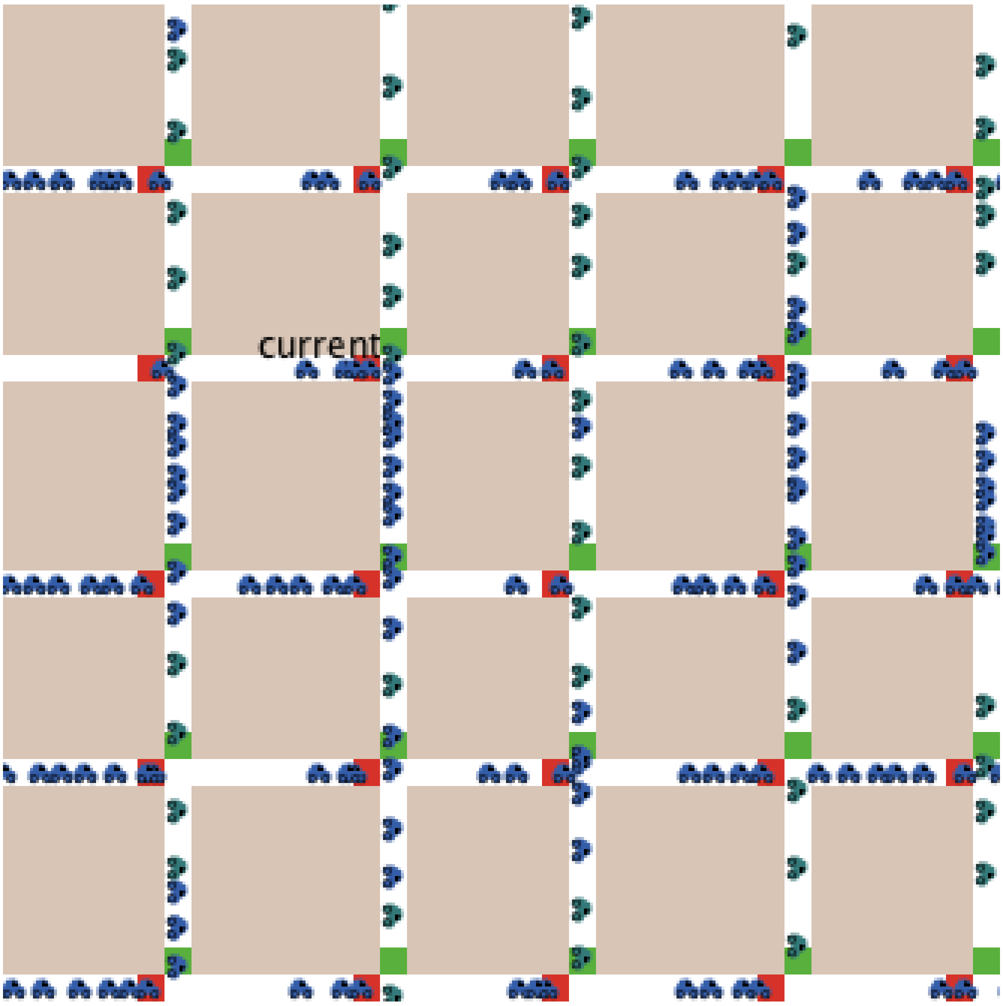

Figure 4.5: A Grid Model

the intersection at the same time without any conflict.

2. Traffic Phase Plan defined as the sequence of traffic phases in time.
3. The Traffic Cycle defined as one complete series of a traffic phase plan executed in a round robin fashion.
4. The Traffic Cycle Duration as the time of one traffic cycle needed for the green and red time durations for each traffic signal.

This makes use of WSN as tool for traffic management in order to reduce congestion.

4.4 Miscellaneous

4.4.1 6-Lane Model

The model is based on the latest trends in the highways. The 6-lane model comprises of lanes having a variable speed-limit criterion . Each of the 6-lanes across the horizon is connected to the source and sink. the vehicles are generated in an randomized distribution at the source thereby giving a real world environment at more precision. Each vehicle as agent incorporates the vehicle following and lane changing mechanism. However the lane changing occurs only at certain conditions assuming the driver keeps his safety at highest priority and avoid any emotional decisions. It takes place either while overtaking the vehicle ahead and tries to minimize the distance by increasing speed ,or when the speed exceeds the limit of the lane.Inorder to change the direction the vehicles in an highway needs to wait for the junction to cross the divider as shown below :

Considering the general architecture of the highways the opposite roads marks the inflow of traffic are governed by traffic lights at each junction . However, the junctions are not directly opposite to avoid congestion. The lights alternates at fixed intervals and governs the rules for traffic flow in the density . Each vehicle moves into the lowest speed lane and then subsequently they increases their speed and change the lanes.

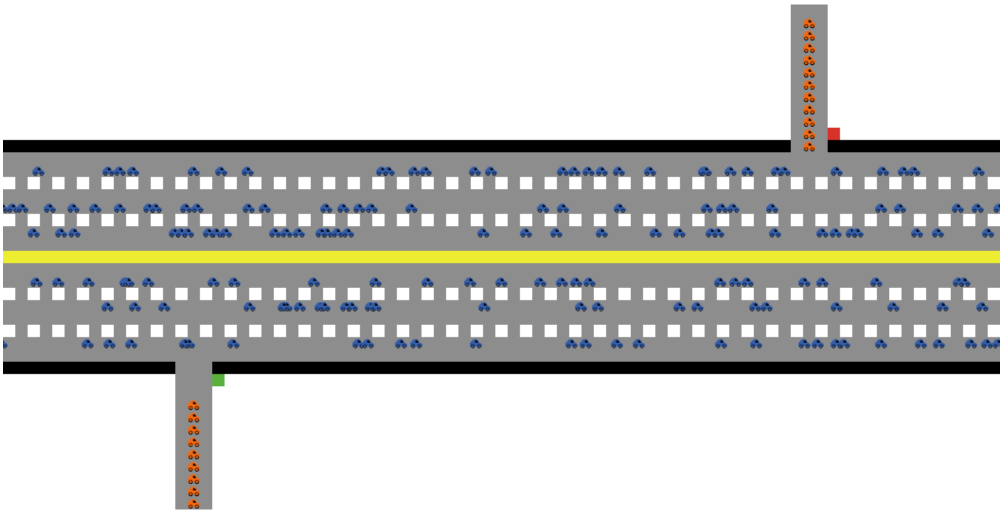

Figure 4.6: A 6-lane model

4.5 Urban Intersection Model

Simulation in a Urban environment comes with many constraints. They need to follow specific behaviors to achieve realistic traffic simulation in such an environment.Some examples of the features can be different road structures, traffic lights, roundabouts, obstacle avoidance , turning onto side roads, turning at junctions, traffic signs at those junctions, overtaking at the target lane and many more. These can be implemented using the vehicle specific behavior rule for each feature which needs to be incorporated with the vehicle following and lane changing models. However the decisions made at the junctions where the car has multiple target lane depending upon the traffic density and the traffic lights. At those points the decision involves many constraints. Such a scenario is presented in this Urban Intersection Model.

The model comprises of three types of agents - the vehicles, roads and the traffic lights. Each agent serves its own purpose. The vehicle agents as general incorporates the vehicle following and the lane changing mechanism for anti

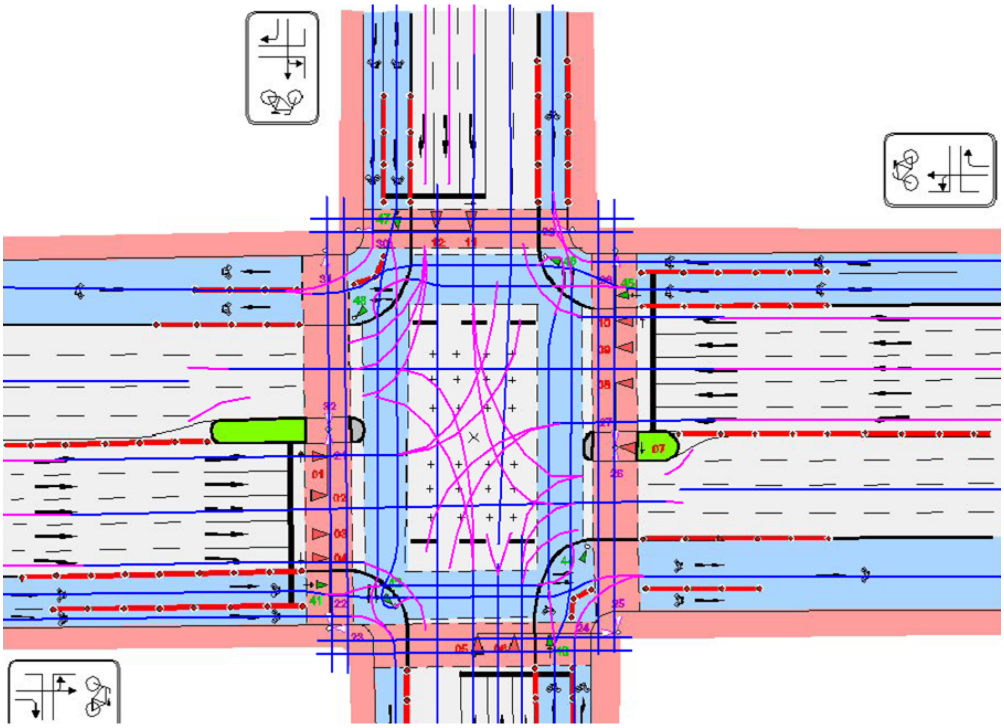

Figure 4.7: An Urban Intersection Model

- collision, avoidance and speed control. Each lane(road) is associated with a traffic light which works independently . The traffic light agents for such complex systems alternates the phases between the red phase to green phase depending upon the traffic density of the lane (road). The Road agents carry the information such as traffic density that is the ratio of number of vehicles on the road by the length of the road segment. This information is shared across all the agents in the intersection. More precisely, a single lane is connected either to a source or a sink or a connector which connects it to two or more road segments. The traffic density of each road segment is shared across the connectors similar to the case of packet switching and in this case the connectors or intersections are analogous to a router. the decision is made by vehicle, roads and traffic light.

4.6 Open Street Map Models

The first step to model a real road network in Figure 5.9 is to know the length of the road links and their location of the junctions. By using a Google map, the lengths of each link in question are measured in metres. The section of the modelled Road modelled is shown below.

In the model, all the angles are considered and the road is turned into a

Figure 4.8: An Open Street Map Model with no angles considered

vivid grid pattern. The lanes are modelled as both HOV and normal lanes. The vehicle composition is heterogenous and it varies with their color, shape and size . To simplify the problem, only intersection roads are considered . The model incorporates the Lane intersection and the urban intersection model as aggregates . The vehicle agents follows the vehicle following , lane changing , and the speed criterion .In order to model this network, the real world units needs be converted into patches. Each road segment is connected to sink, source or a connector

. Each road segment is scaled to specify its length , width and capacity along with other technical criteria such as speed limit or mapping to other roads at the junctions and traffic lights respectively .

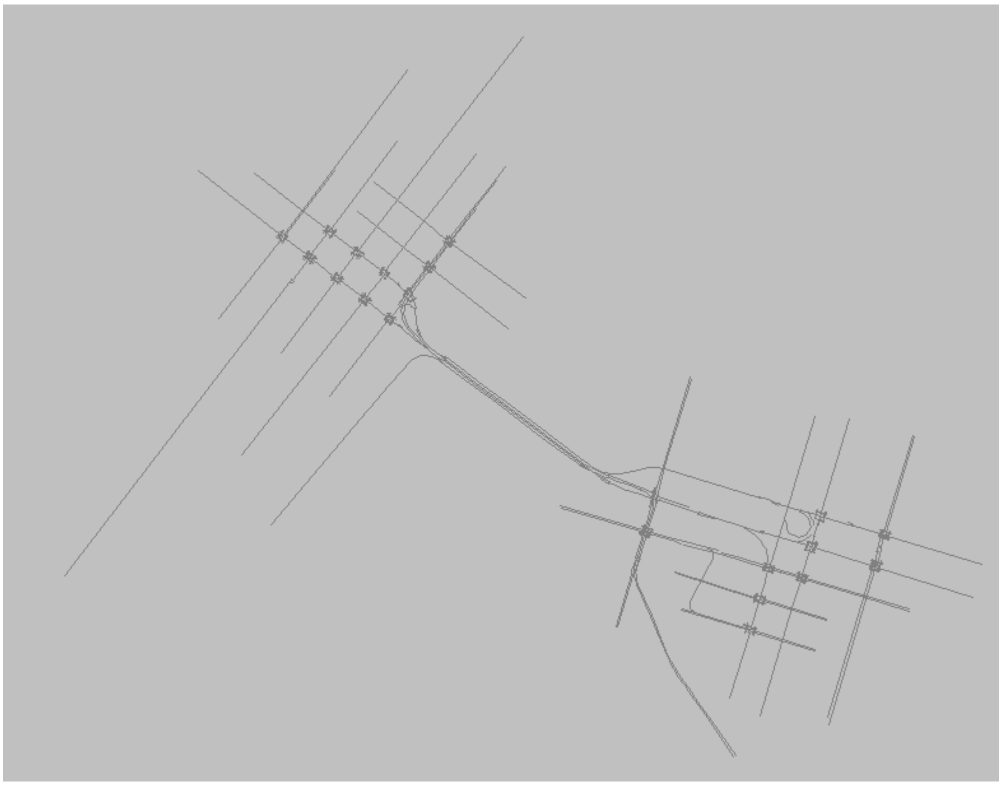

Figure 4.9: An outline of an Open Street Road Network

Figure 4.10: An Open Street Map Model with angles considered

Chapter 5

Results and Discussions

Implementation and evaluation of each models outlines in the previous section is discussed in this section.

5.1 Design and Functional Discussions

The models constructed successfully meets the functional requirements of each model respectively.Following are the list of interface design requirements that are met in the project are listed below:

1. Model has the ”New” or ”Setup” button that clears all the preexisting parameters and resets them to their respective default values.
2. Models has ”Save” button which allows the user to save the changes made and record the observations.
3. Model has ”Load” button that is to load a preexisting model which was saved earlier.
4. Model sets the time events to ”discrete” time step functions.

5. Models allows the user to input for the number of vehicles for the number of vehicles to be generated at any time in the model framework.

6. Model allows the visualisation in both 2D and 3D as well.

7. Model shows the vehicle following behavior well.

8. Model shows the plot of ADT of each selected vehicle over time as shown below Figure 5.1 and Figure 5.6.

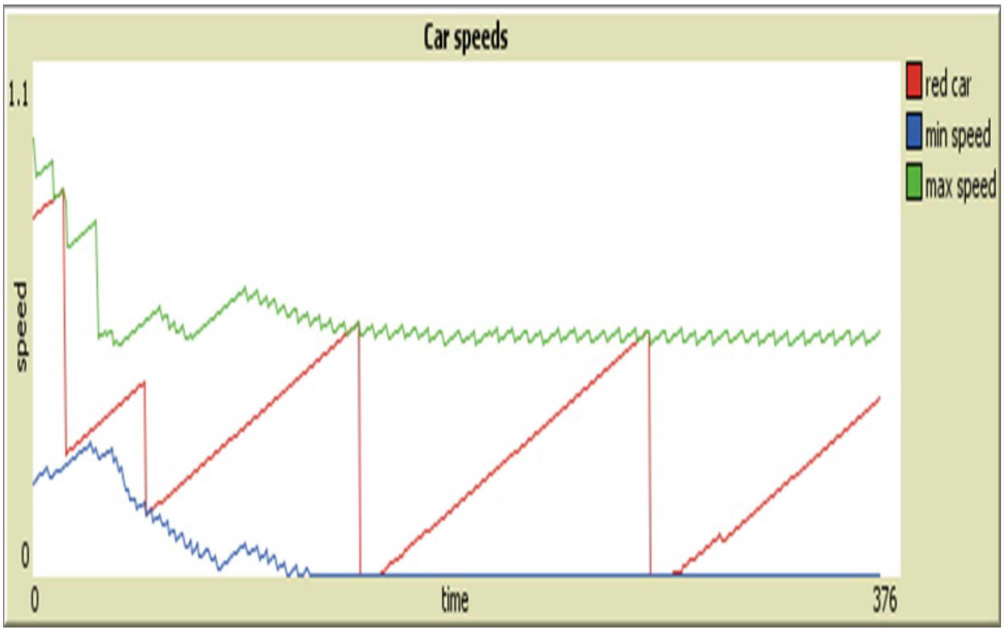

Figure 5.1: The ADT for a Single Lane model incorporating Vehicle following

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each vehicle has an independent behaviour based upon its speed , speed-limit , maximum acceleration , maximum deceleration , lane number in case of multiple lane model , and these are implemented well in the vehicle following behavior . The systems were designed to such that each vehicle occupy one patch of the space when either it is moving or when it is stopped in a queue. This allows the vehicle speed to be calculated in real space units that is in terms of patches per units since the tools knows about the patch length and the vehicle and the speed of vehicle . The vehicle following algorithm allows the tool to model the core functionalities of the vehicle interactions that would make the driver stop if there is an obstacle or a stopped vehicle ahead . This is similar to the emergency 2 second rule where the driver intend to keep a 2 second worth of gap between the vehicles[25].

5.2 Behavioral and Performance Discussions

After meeting the design and functions criterion in phase 1 , We move to phase 2 .Phase 2 level testing of vehicles tests the microscopic behavior of the entities. It ensures that the vehicles following a single lane adhere the certain behaviors along the lane.

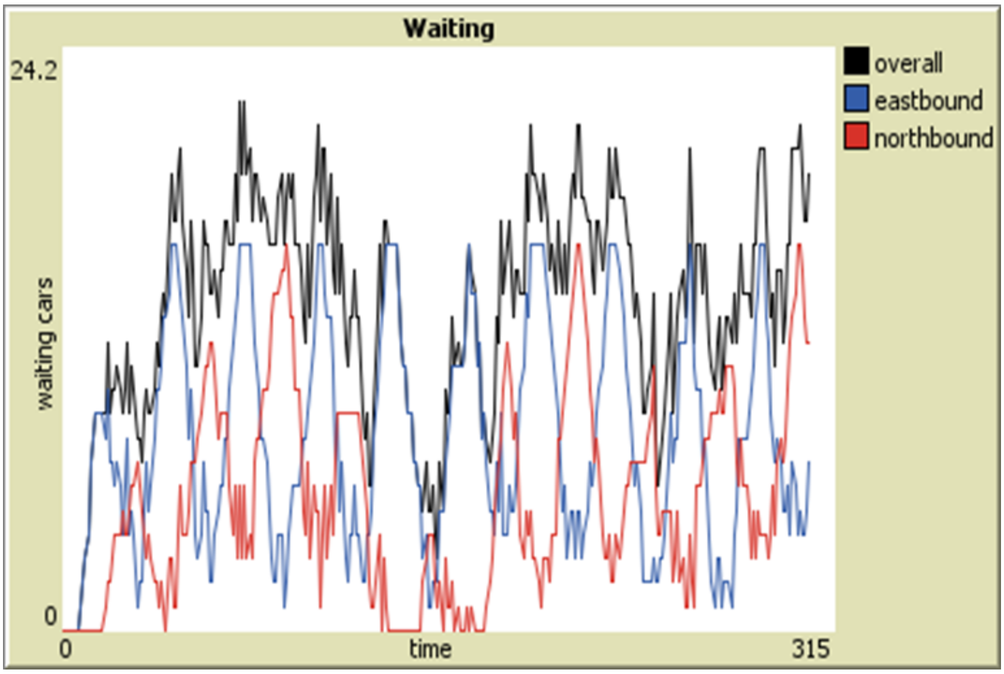

Figure 5.2: The Waiting time graph for Intersection model for a single lane

1. Consider the case when the of a single stopped vehicle in the single lane , then the models simulates the behavior such that the vehicle stops with specific deceleration as they approach the stopped vehicle and it stops moving exactly one step behind in Figure 5.2.

2. Consider another scenario where there are very few vehicles on the lane , the vehicles moves free flow continuously .

3. Consider the case when there are many vehicles on the lane but none stopped vehicles , then the vehicles forms a traffic jam and they need to move backwards as in a time space diagrams .

4. Again when there is a single lane with repeating traffic light , then the vehicles must follow the signal that is they should stop vehicle when the light is red and they form a queue in Figure 5.4.

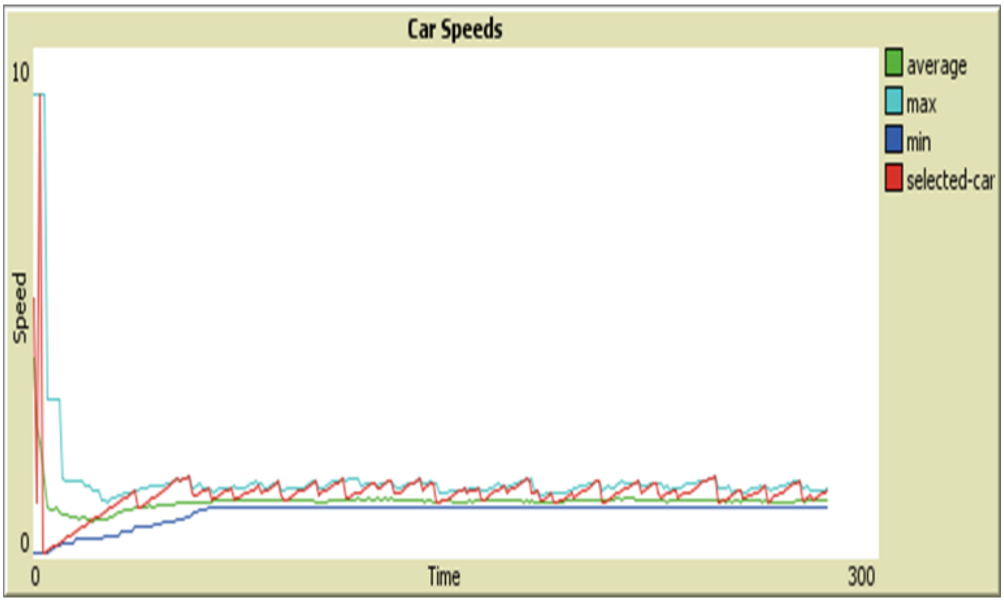

Figure 5.3: A speed-time graph for multiple lane model

However for multiple lane models the vehicles follows some additional behaviors which are listed below :

1. When there is stopped vehicle in a lane , then the vehicle following should move out of the lane to pass the stopped vehicle and then can optionally move back to the lane ,Figure 5.3 .
2. When there is a single lane with repeating traffic light , then the vehicles must follow the signal that is they should not move past the stopped vehicle by switching to the other lane , but should stop vehicle when the light is red and they form a queue.
3. when it is connected to the single lane road at its left junction as in 6-lane model , then most vehicles drive on but some also move on to the side road for realistic behaviors .
4. In the previous scenario , some vehicles also enters the main lane by following the traffic lights.

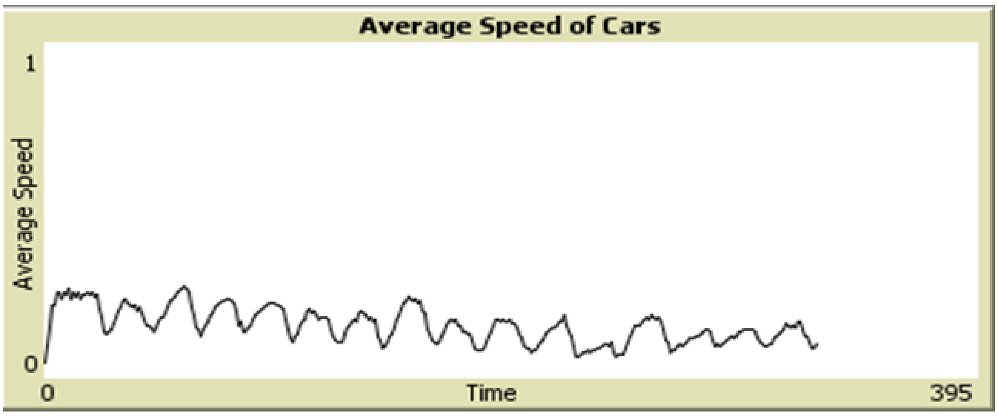

Figure 5.4: A grid based model for Average Speed of Cars

5.3 Open Street Maps Simulation Discussions

This level is evaluate the necessary features of the urban simulation. The simulation in such large system is accompanied using a simulation tool of VISSIM .The model satisfies the following criterions listed below :

1. Models are flexible enough to add sinks, sources and traffic lights using the edition tool box. Roads are multi- directional and controls which way the vehicle should move. Each road is also characterised with its speed - limit .
2. the traffic signals can simply be added or removed at any point in time. even the timing phases of traffic lights can be altered using the agents inspectors.
3. lane changing behaviors was the most difficult to implement since it depends upon many constraints.
4. Since the roads have directions , they are connected to corners or junctions. Vehicles following each other along the road stops if there is queue ahead.
5. each Road has its own traffic light and the vehicles follows the basic rules of signals.
6. traffic light forces the vehicle to stop when it is red . The phase between the green times can be coordinated wisely.
7. travel time for each vehicle is computed as they enter and leave the system.This time is recorded and graphed.
8. Traffic density of the vehicles at any time in the intersection is modelled in the space.

it is always considered that the driver behavior is analogous to keep his safety at the first priority . With the introduction of agents, vehicles can now check what type of lane they are at, and the corresponding lane configuration , vehicle composition of the surrounding vehicles , and communication with the other agents

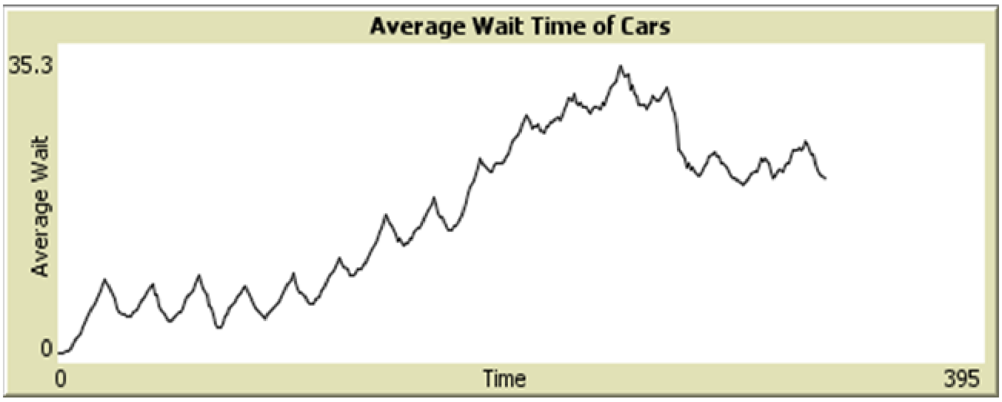

Figure 5.5: Grid based model for complex networks showing the ADT

before taking a decision whether to move left or move right until it is safe. Vehicles can check the lane before moving.

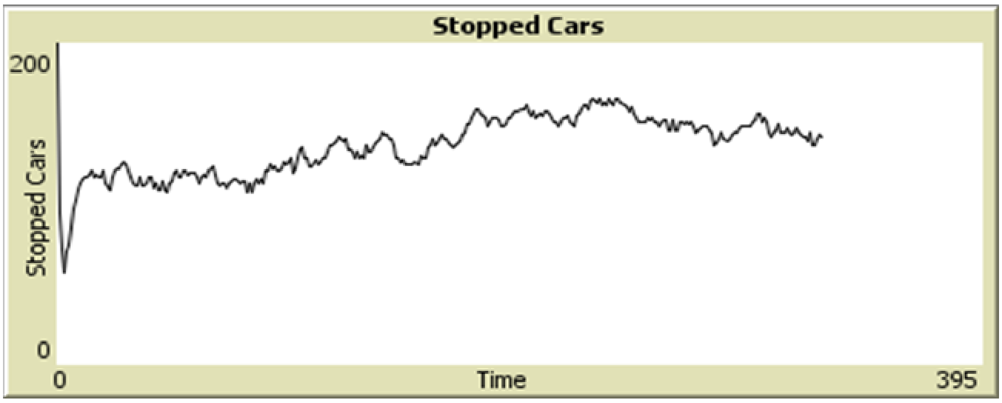

Figure 5.6: A model illustrating the ADT for Stopped vehicles

Chapter 6

Conclusion and Future Works

In this project, a traffic simulator has been developed using NetLogo, an integrated agent-based modelling environment and VISSIM , a microscopic visual simulator. This simulator were used to model different attributes of the real world road networks .The Features that have been implemented includes vehicle-following , lane-changing, sources, sinks, traffic lights, speed - limts , HOV lanes, traffic flow, traffic density , journey times , delay time ,vehicle composition , vehicle occupancy , road angles , road mapping , and Multiple Lane traffic distribution with routing decisions at each node. The simulator have been calibrated and validated with known data from the traffic studies, and the testing shows that the simulator can accurately model traffic flow in a various urban and motorway conditions. It has been successfully applied to modelling a large number of road environments including single lane to 6- lane roads , simple intersections to Urban intersections , and basic models to complex ones from Open Street maps through any surveillance to model the real worls roads and then to analyse their effectiveness.

When it applied to the problem of analysing congestion, simulation proves to be a useful tool. Since it is cost effective and efficient tool and can handle complex data with precision .Promising results are revealed when the Simple intersection model is run with and with considering the signals as agents in each lane, suggesting that the ADT of each road segment is lower and the travel times are reduced substantially for users and not affected for others. The traffic density distribution even follows the same results .According to the results of the simulation, incorporating agent based communication is certainly effective . The only calibration data that was not properly considered were vehicle input rate, however this may not be an important parameter as long as vehicles enter at identical rates in both ends at randomized pattern. Investigation into the effects of other congestion reducing schemes and in other study areas is left for future work .

The most challenging requirements were to address the lane-changing behaviours. This was expected due to the amount of attention they receive in the literature. Resulting vehicle behaviour is then mostly realistic especially at the macroscopic level; however, it could also be improved by thorough further analysis. The Driver characteristics were not modelled and assumed that they are expected to keep their safety at first priority and strictly follows the vehicle driven model; however, there are two types of models in real world , one is the user- driven and other is vehicle - driven scenario . In both these models the vehicles acts as intelligent agents. The vehicles following the above discussed mechanisms assess the surrounding vehicles and lane parameters and takes decision on its own without the drivers consent in a vehicle driven model.However ,vehicles do have individual maximum speed/acceleration resulting in a degree of perceived driver characteristics.In such a user- driven model the vehicles inform the driver about the current parameters and warnings and then the drivers takes the final decision. This process of implementing driver controls is a part of the Future work . Future works on this project also includes any further calibrating inputs/behaviours from interface controls, verifying simulation output and then implementing more features/indicators along the lanes and across the junctions. The major applicable feature not implemented was public transport, in particular buses. Other important features to be considered are more events ,pedestrians and adaptive traffic signals, among many more.

The agent approach to the traffic simulation is very well justified, since all the vehicles and traffic control features can also be represented directly as an intelligent agent. It makes the problem much easier to tackle by allowing the developer to focus only on modelling the individual agent behaviour. Agent-based modelling even allows a traffic simulation to be much easily implemented using the agent techniques. NetLogo was a key tool . which provided extensive functionality with object oriented approach ,while being highly learnable. It is highly recommended as a novice into the agent-based modelling concept, and made development time extremely productive. However the bottlenecks of NetLogo includes their performance limitations for a large number of agents. Then the execution speed drops considerably. NetLogo is not designed for any detailed or extensive simulations for large systems.

However VISSIM helps to resolve such conflicts and it made possible to model large networks such as open maps and even a city models . They model networks using the traditional nodes and links constructs , because patches are always intended to represent the environment and agents could act as links. The interface editor is quite impressive. It is also suitable for 2D and 3D visualisation of large world sizes; where the entire world is shown in the visualisation window.It is made extremely large in order to enable model the editing.

A great deal of knowledge was gained about the specifics, details of traffic simulation and agent-based modelling during the course of the project, and both from research literature, journals and from a personal experience during the development. The aims and objectives of this project that were set out in the introduction have been successfully met, and this report accurately represents the few steps taken to achieve those objectives. In conclusion, this project could be considered a success based on the reasons outlined above.

Chapter 7

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